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PROCEEDINGS

IN-09-CR

Real-Time Simulation Development for Aerospace Applications

Requirements Generation for Aerospace Applications

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December 5, 1989

University of Houston-Clear Lake

Bayou Building 1-311

Co-Sponsored by:

NASA/ Johnson Space Center

University of Houston-Clear Lake

McDonnell Douglas, Inc.

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Sigh	Bik	UNISYS	U07B-16
Smith	Scott	UNISYS	I07B-16

Real-Time Simulations for Aerospace Applications Series

Requirements Generation for Aerospace Applications

Agenda

Introduction — **Jim Allison**
Senior Manager, Systems Development
McDonnell Douglas Space Systems Co.

Session 1 — **Relationship Between Training Requirements, Behavioral Task Design, and System Supportablity**
Ronald G Hughes, Ph.D.
Staff Scientist, Advanced Programs
McDonnell Douglas Helicopter Co.

Session 2 — **Visual System Requirements: A Comparison of Aircraft and Space Station Environments**
Richard Schwartz
Engineer, Visual Display Systems
McAir Training Systems

Session 3 — **Attempting to Make Real Requirements**
Charles Zumba
Chief Engineer and Corporate Vice President
Space Applications International Corp.

Aerospace Simulation Working Group

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Real Time Simulation Development For Aerospace Applications

Requirements Generation for Aerospace Applications

December 5, 1989

University of Houston at Clear Lake

M8912433-1

MCDONNELL DOUGLAS

Simulation: A Practical Definition

An attempt to model the essential relationships between those variables having a direct impact upon system performance.

- Simulation is a "means to an end"
- System specific and focused
- Only essential variables and their effects
- Variable fidelity requirement

M8912433-2

MCDONNELL DOUGLAS

Applications Drive Requirements

- Concept Development
- Engineering Design
- Test and Evaluation
- Training
- CRAD / IRAD Support

M8912433-3

MCDONNELL DOUGLAS

Overcoming Common Misconceptions

- All Simulators are not training devices
- "Simulation" not restricted to Man-In-The-Loop
  - COMBAT SIMULATION as an MDC Strategic Technology
  - An example of a Simulation Life Cycle Concept

MCDONNELL DOUGLAS

Critical (Strategic) Technologies

Advanced Flight Technologies

Advanced Materials & Structures

Anti-Stealth

Artificial Intelligence

Computer & Software Technologies

Integrated Design, Manufacturing and Logistics

Low Observables Technologies

Manufacturing Technologies

Aircrew Machine Interface

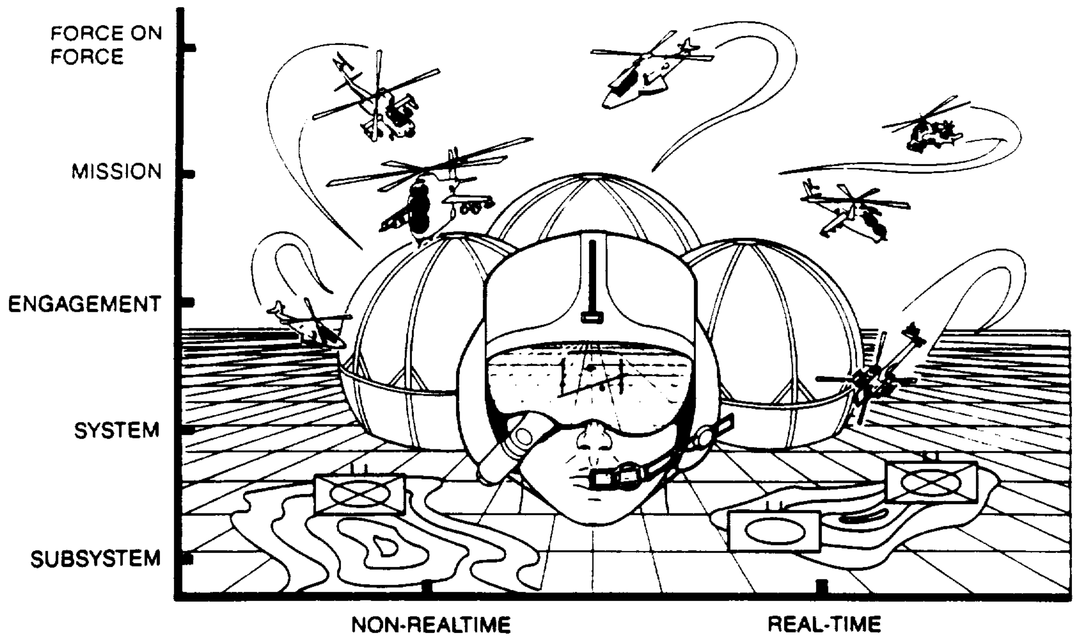
Sensors / Avionics / Photonics

Supportability

Survivability / Lethality

Combat Simulation

Integrated Guidance, Navigation and Controls



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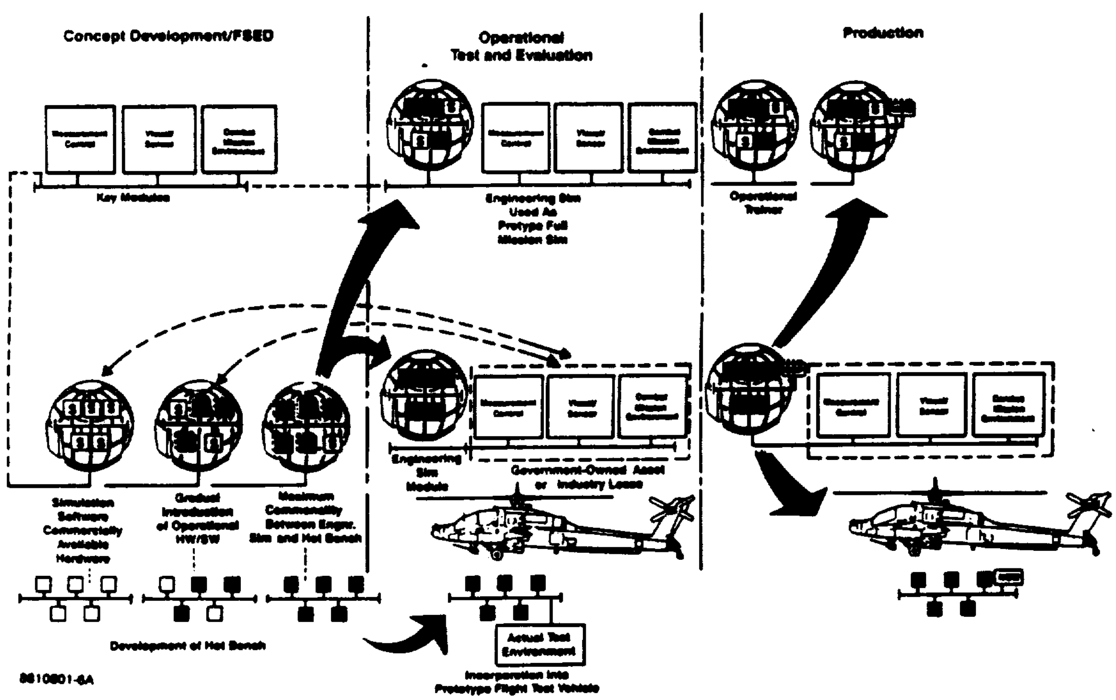
MDHC Simulator Utilization Concept



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Focus Of This Discussion

Manned, Real Time Simulation

for

Aerospace Applications

M8912433-7

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Simulation Components Nominally Considered

- The "Visual" System (Image Generation, Display and Data Base Subsystems)
- Computational System
  - "Simulation -vs.- Stimulation"
  - "Common Operating Environment"
- Force Cueing
- The "Operational" (i.e., Mission/Threat) Environment
- System Control and General Operating Concept
- Performance Measurement, Data Collection, Analysis
- Interface to Other Devices (eg, Hot Benches, local and long-haul networks, etc.)

M8912433-8

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The Visual System: Major Requirement Issues

- Image Generation
  - Image Generator Channel Requirements

    Out-the-Window and Sensor requirements, Number of Independent Eyepoints

  - Use of Correlated Image Generation Systems

    Auxiliary players, moving map displays, tactical situation displays, etc.

M8912433-9

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Visual System Requirements (cont.)

- Display System
  - Field of view (FOV) and Field of Regard (FOR)

    Area of interest systems, fixed displays, head/eye tracking, helmet systems, etc.

    A-10 Simulation Examples (FOV and critical visual cues; offensive/defensive effects on performance)

    Station Proximity Operations Example

  - Brightness and Contrast and relationship to Resolution

    Examples from air combat maneuvering studies

M8912433-10

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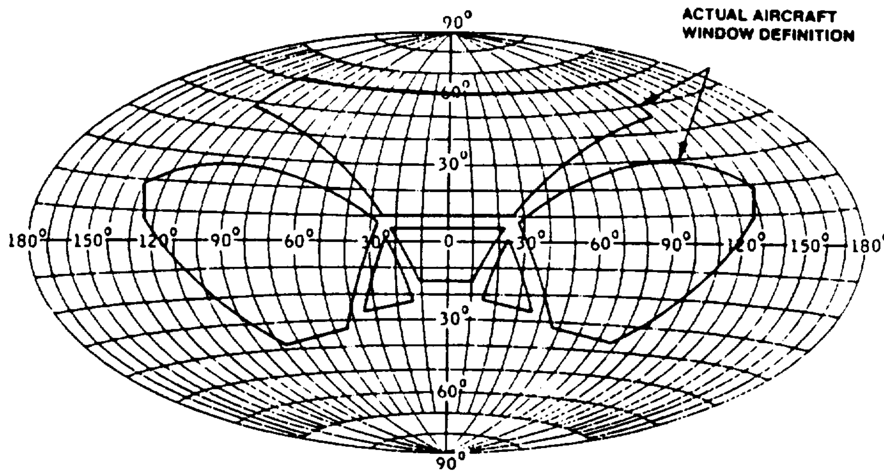
Aircraft Window Definition
Apache Pilot Station



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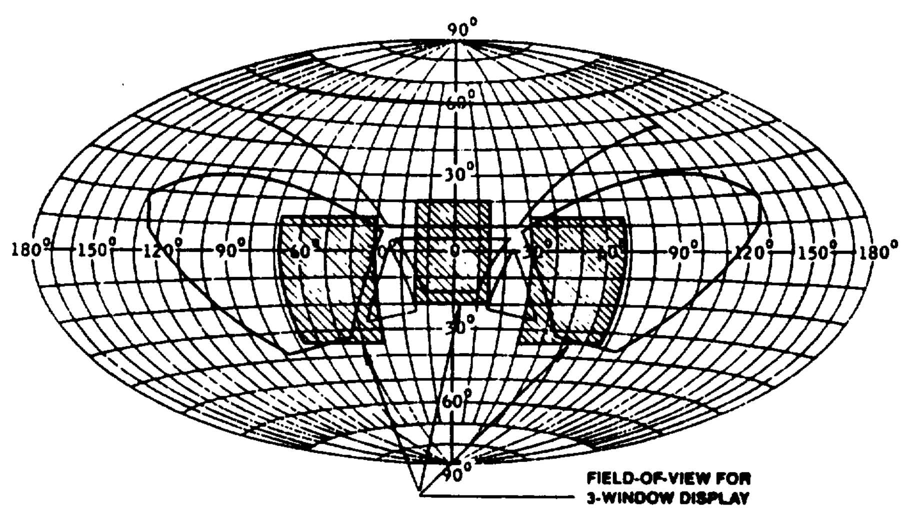
Field-Of-View
For Apache Pilot In Singer CMS



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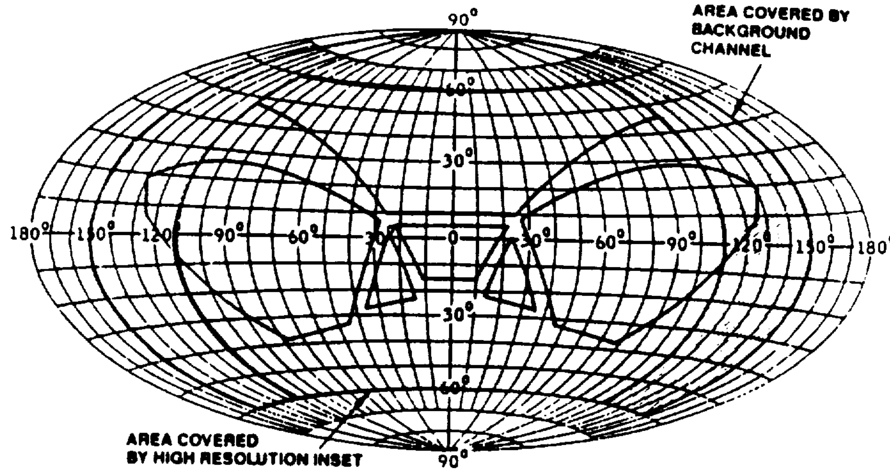
MCDONNELL DOUGLAS

Simulator Field-Of-View For Apache Pilot Using MDHC Servo-Optical Projection System (SOPS)



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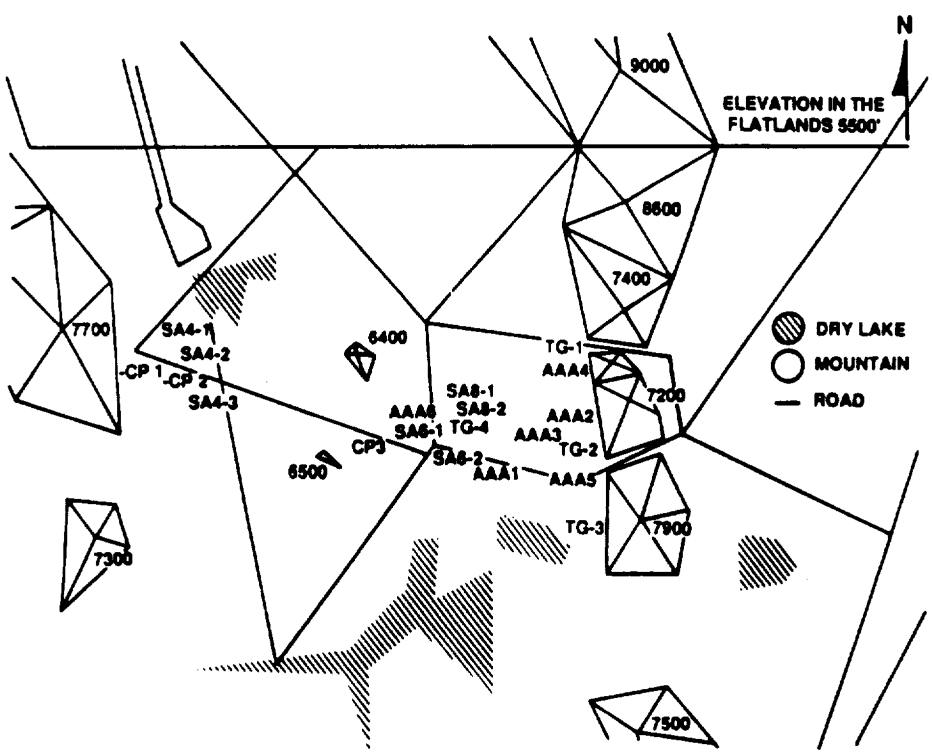

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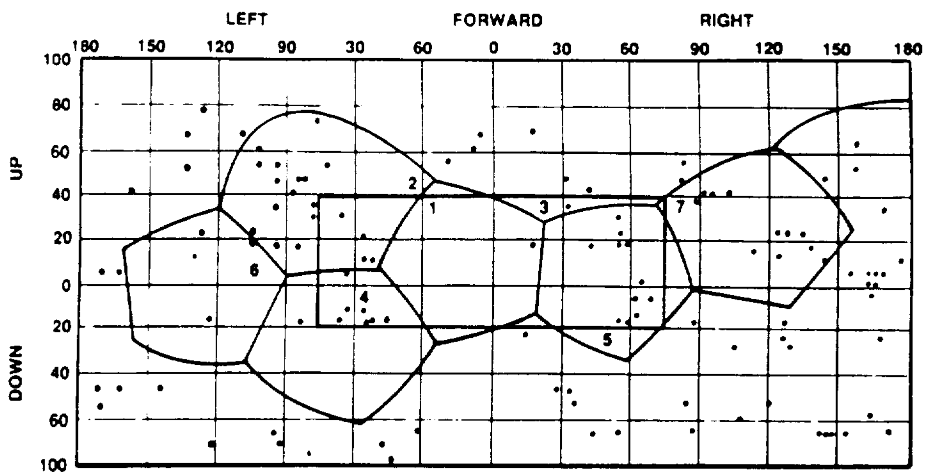
(FROM HUGHES, GRAHAM, AND BROOKS, et al., 1982)



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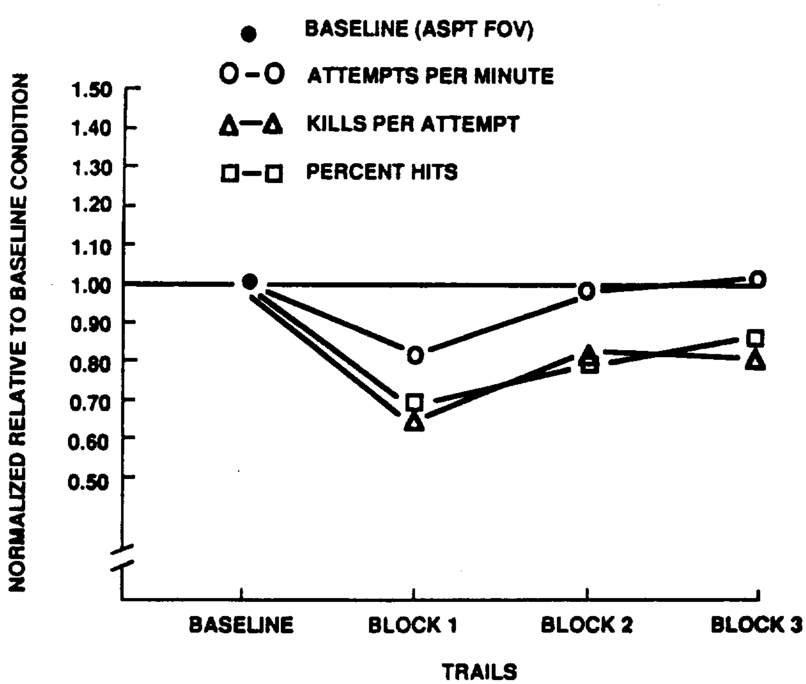

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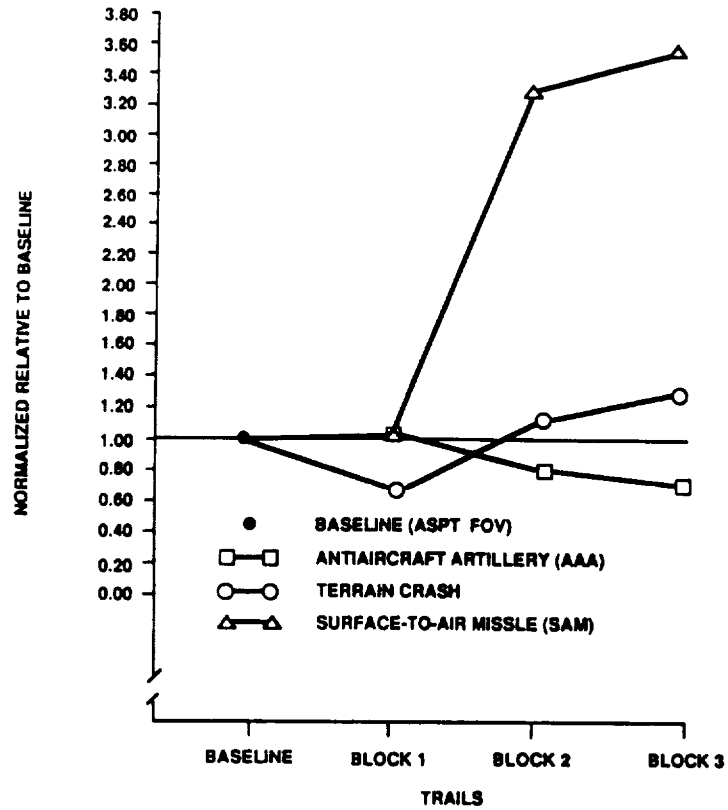

(FROM HUGHES AND BROWN, 1985)

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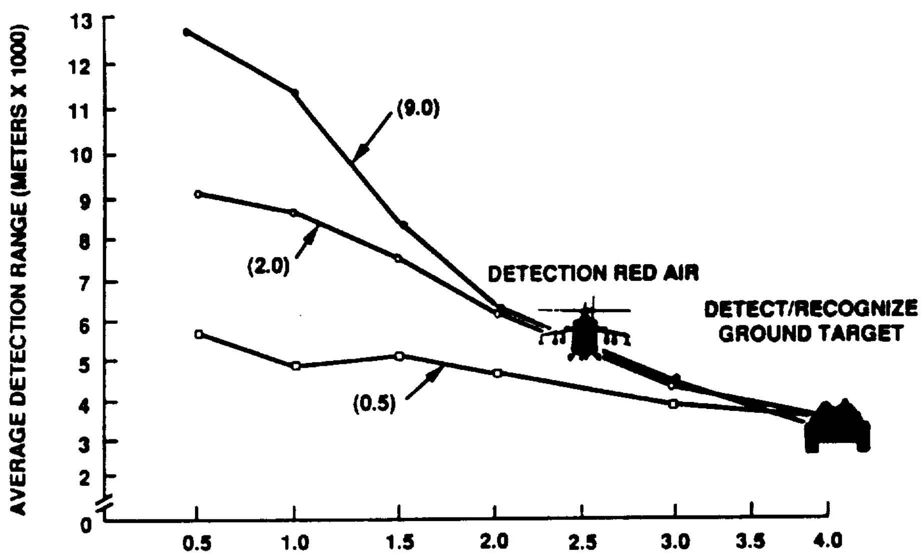
AVERAGE DETECTION RANGE AS A FUNCTION OF DISPLAY RESOLUTION AND TARGET CONTRAST

(HEAD-ON SCENARIO)



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(FROM KERCHNER, LEE, AND HUGHES, 1983)

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Visual System Requirements (cont.)

- Visual Data Base
  - Scene content/detail, fidelity, and polygons

    An example of Apache Helicopter requirements

    Data Base considerations in SPOT

    Role(s) of texture capabilities
  - Relationship between Field of View, Scene Content and Resolution
  - The Line of Sight (LOS), Intervisibility Problems
  - Common Data Base (Project 2851)

M8912433-11

The Attack Helicopter Mission

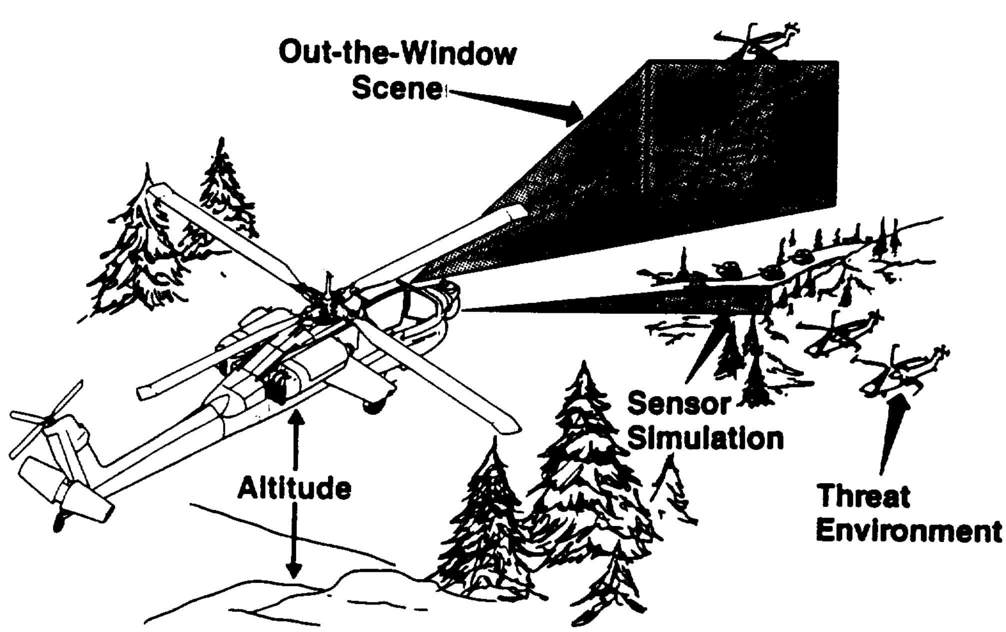

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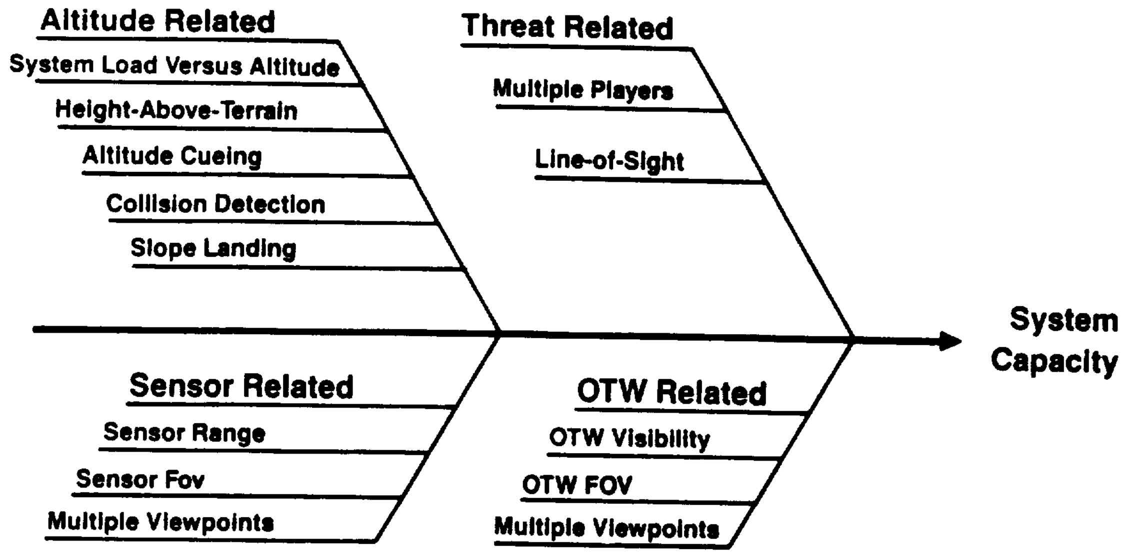
Image Generation Issues



System Load
Night Mission Example

	Channel	FOV (Degrees)	Terrain Visibility Range (km)	3D Culture Range (km)	2D Culture Range (km)	Visible Polygons
OTW	1	120×90	1.5	1	1	136
OTW	2	40×30	1.5	1	1	45
OTW	3	120×90	1.5	1	1	136
OTW	4	40×30	1.5	1	1	45
Sensor	1	18 (Diag)	20.0	15	15	2,928
Sensor	2	50 (Diag)	20.0	15	15	8,078
Sensor	3	4 (Diag)	20.0	15	15	652
					Subtotal	12,020
Threats		15 Active				750
Special Effects		5 Active				75
					Total	12,845

Assumptions

1. Terrain Density = 42 Polygons/Sq Km
2. 2D Culture Density = 42 Polygons/Sq Km
3. 3D Culture Density = 3 Features/Terrain Polygon
4. 3D Culture Complexity = 6 Polygons/Feature
5. Average Polygons/Moving Threat = 50
6. Average Polygons/Special Effect = 15

System Load
Day Mission Example

	Channel	FOV (Degrees)	Terrain Visibility Range (km)	3D Culture Range (km)	2D Culture Range (km)	Visible Polygons
OTW	1	120×90	7	5	5	3,277
OTW	2	40×30	7	5	5	1,092
OTW	3	120×90	7	5	5	3,277
OTW	4	40×30	7	5	5	1,092
Sensor	1	18 (Diag)	20	15	15	2,928
Sensor	2	50 (Diag)	20	15	15	8,078
Sensor	3	4 (Diag)	20	15	15	652
					Subtotal	20,396
Threats................15 Active						750
Special Effects.......... 5 Active						75
					Total	21,221

Assumptions

1. Terrain Density = 42 Polygons/Sq Km
2. 2D Culture Density = 42 Polygons/Sq Km
3. 3D Culture Density = 3 Features/Terrain Polygon
4. 3D Culture Complexity = 6 Polygons/Feature
5. Average Polygons/Moving Threat = 50
6. Average Polygons/Special Effect = 15

M8114174

MCDONNELL DOUGLAS

Computer System Requirements

- Requirements driven by particular simulator applications.
- Engineering simulator must be able to accept operational aircraft hardware and flight software.
  - Simulation versus stimulation considerations
  - Simulator / aircraft concurrency
- Distributed architecture, networking, bandwidth
- Higher-order programming language (e.g., Ada)

M8912433-12

MCDONNELL DOUGLAS

Requirements For Force Cueing

- Platform Motion (6DOF)
- G-Seats / Suits
- Seat / Stick Shaker Systems
- Fixed-Wing vs. Rotorcraft requirements
- Zero-G environment

M8012433-12a

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Flight Model Fidelity and Handling Qualities

- Who has responsibility for real-time flight model development?
- How will simulator handling qualities be evaluated?
- What are inherent limitations of ground-based simulator? What should be done in air vehicle and what should be done in simulator?
- Are there special computer requirements associated with running flight model (e.g., rotor map vs. blade element)
- Must simulator be able to accommodate actual flight test data (e.g., use recorded aircraft data to drive simulator)

M8012433-13

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From Little Simulators Big Trainers Grow

Will Trainers be evolved from Engineering Simulator design?

- Use of modular approach
- Mil Spec vs. best commercial practice
- Operational H/W requirement for SIM?
  - Long lead time items, CFE, GFE, Supportability, etc.

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The Simulation "Environment"

- Common data bases and modules
- Meteorological considerations (e.g., weather, time of day)
- Operational environment
  - Other players (how many, how interactive, how many real-time, what fidelity?)
  - Computer driven (how "smart")
  - Local vs. remote players(networking/bandwidth)

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System Control Requirements

- Who will operate station (how user friendly)?
- What unique features will be required?
- Real-time monitoring requirements?
- Will control station support measurement requirements (raw data and/or processed data; on-line or off-line analysis, etc.)?
- What will be span of control of station (e.g., in terms of other local and/or remote devices)?

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Performance Measurement Requirements

- Driven by specific simulator application
- Must support/augment conceptual framework of user (e.g., design engineer, trainer/instructor, system operator, etc.)
- Must maximize use of real-time feedback to simulator user
- Emphasis upon real-time, pictorial displays with simple descriptive statistics (central tendency, variation, etc.)
- Reduce requirement for analyses and long turnarounds due to off-line analysis
- Must be consistent with measurement systems used for flight test and mission effectiveness analysis

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Facilities Requirements

- Is there residual facility capacity to support program? (platforms, IG's, display systems, system control, etc.) Are there major capital requirements?
- Will simulator have to share resources from ongoing programs?
- Does sim have to be run in totally secure (TEMPEST) environment?
- Are there requirements to network outside the local simulator environment?
- Is there proprietary hardware/software involved in establishing these networks/interfaces?
- Are there long-haul communications requirements which have security requirement?

M8912433-18

33

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Programmatic Issues

- What is relationship between Government and Industry in terms of the application of simulation?
- Will products developed to run on the contractor's simulator be required to be transported to a Government facility for integration/evaluation?
- Will the effectiveness of products developed by the contractor and demonstrated on the contractor's simulator be required to be exercised remotely (e.g. by long haul communications link) in some Government-run simulator environment (e.g., SIMNET)?
- How will various simulator users on the Government side coordinate their development and evaluation activities? Will the real Government customer please stand up?

M8912433-19

Requirements Generation For Real-Time Simulation
-An Aerospace Perspective-

SUMMARY OF KEY POINTS

- Simulation requirements cannot be limited to real-time, manned simulation alone.

- Common Operating Environment essential to effective use of simulators/simulation as a design tool. Biggest impact upon computational system architecture.

- Issue of common operating environment with respect to simulation extends to Government-Industry working relationship.

- Networking (both locally and long-haul) becoming an increasing requirement.

M8812433-20

Requirements Generation For Real-Time Simulation
-An Aerospace Perspective-

SUMMARY OF KEY POINTS (cont.)

- Simulation fidelity must be understood in the context of the specific application (i.e., concept development, engineering design, test/evaluation, training, etc.)

- Image generation and display system requirements (i.e., the "visual system") continue to be biggest cost drivers for aerospace applications.

- Judgment required in selective use of simulator versus flight vehicle for handling qualities and control law development.

M8812433-21

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VISUAL SYSTEM REQUIREMENTS

A COMPARISON OF AIRCRAFT AND SPACE STATION ENVIRONMENTS

Presented By:
Richard J. Schwartz
MCAIR Training Systems
McDonnell Douglas Corporation

Visual System Requirements: A Comparison of Aircraft and Space Station Environments

Richard Schwartz, Engineer, Visual Display Systems, McAir Training Systems, McDonnell Douglas Corporation, St. Louis, Missouri.

The following notes were taken from the presentation.

This presentation will compare the visual systems requirements of aircraft and space station from a human engineering perspective.

Visual Arenas:

The visual requirements of the aircraft and space station environments have similar and unique features. Basically, there are 3 different visual arenas:

1) the near-field inside the cockpit/cupola,
2) the near-field outside the cockpit/cupola, and
3) the far-field.

The near-field inside the cockpit/cupola:

This field includes those things that you can manipulate or control within the cockpit or cupola (example, the throttle), and those that are displayed immediately within the cockpit/cupola (gauges and other displays, for example). This arena is virtually the same whether in the cockpit or in the cupola.

The near-field outside of the cockpit/cupola:

In the aircraft environment, objects exist only briefly, if at all, in this arena. Thusly, the simulation and training of this arena is a low-priority in the aircraft industry. This arena is significantly more populated in the space environment, however. Objects such as the space station and free-flying objects appearing outside the cupola in the near-field space environment often

require intensive eye-hand coordination and manipulation -- consider transferring cargo or grappling a free-flying object, for example.

The far-field:

In an aircraft environment, the objects in this arena are either on the ground or in the air. The entities in this environment can range from fixed and non-intelligent, such as trees, to non-fixed, highly-intelligent enemy aircraft. Likewise the space environment will have a variety of stimuli -- celestial bodies such as the moon and stars, or free-flyers such as other spacecraft. In both environments, viewed objects appear to be nearly at infinity.

The greatest difference between the aircraft and space station visual environments exists in the near-field outside the cockpit/cupola. This difference prompts the need for development of visual simulation requirements for eye-hand coordination training.

Visual requirements for a successful eye-hand coordination training program:

The first visual requirement is depth perception, or how we perceive position within an environment. Second is display accuracy, or how well the scene is presented to a person.

Depth perception cues are either monocular or binocular, with the first being interpreted psychologically, while the second is interpreted physiologically. The monocular cue requires only one eye to see the object, which will give a partial image of the object; but which the mind will interpret psychologically as a whole. For example, the eye seeing a part of a hand positioned

behind an object will psychologically interpret that there exists a whole hand, and can visualize its location. A binocular cue requires two eyes simultaneously to make the correct interpretation. To illustrate this, focus on an object at a distance and then shift to a nearer object. The eyes converge, providing an image position based upon triangulation.

Two types of images can be portrayed. One is the direct view, similar to looking outside of a window; the second image is usually a closed-circuit TV monitor. A monitor display typically projects only monocular-type cues.

As there has not been much experience simulating/stimulating the near-field outside of the cockpit arena in the aircraft industry, there is a need to study two things:

1) What do we need to portray the outside--what cues are important? (It is thought that monocular cues may be a little more important.) Will we need to double everything to make binocular effects, and multiplex these images also? Can we break down the outer near-field into areas where monocular or binocular vision may be best used? Are some cues more case-specific than others?

2) More displays-type studies are needed to develope displays containing correct cues.

Summary:

There is much similarity between the cockpit/cupola view of the near-field inside the cockpit/cupola and the far-field arenas. However, the importance of the near-field arena outside the cupola in space applications is much greater than in aircraft, requiring that more research be done in this arena.

TOWARD REAL REQUIREMENTS

Science Applications International Corporation

Charles Zumba
5 December 1989

NEEDS, WANTS, TECHNOLOGY

It Is Required That:

We Put A Man On The Moon Before The End Of This Decade

It Is Required That:

The Thoughts of Mikhail Gorbachev Be Available To The National Indications Center Within 30 Seconds Of Their Occurence

It Is Required That:

The U.S. Have An Impenetrable Shield Against Ballistic Missiles

POLICY, POLITICS, AND REQUIREMENTS

- Policy and Planning Models
- Honest Abe Doesn't Qualify
- That Was Last Year
- The TOS Solution

REAL REQUIREMENTS START
(Or Requirements For Real People Start)

- There Will Be An Apollo
- There Will Be A B-1B
- There Will Be A TOS
    - If Fly, Then Live

Science Applications International Corporation

REQUIREMENTS AND OVERRUNS
The TAF Advanced Mission Planning System

- World-wide Mission Planning And Support
- ATF, All TAFs, Applicable To SAC And SOCOM
- Rapid (Minutes) Planning
- Supports Inflight Minimum Workload Replan
- What-if?; Perhaps Mission Rehearsal
- Global Weather, Terrain, Cartographic Support
- Full C2I Connectivity
- Multi-level Security
- Totally Pilot Friendly
- Flexible And Growable

SAIC.
An Employee Owned Company

TAF AMPS COMPARISONS

- Color
- Higher Resolution
- Processing Power +1-2 Orders
- Graphics Engine +3-4 Orders
- Memory +2-3 Orders
- Multiple Perspectives
- Smaller
- Lighter
- More Available
- Cheaper

THE REQUIREMENTS FOR REQUIREMENTS

- Within Political and Policy Framework
- Balanced:
    - Capability
    - Money
    - Schedule
- Continued Discipline

REFORMATION

- The Revolution - Cerebral Acquisition Reform
- The Evolution - What Goes Around Comes Around
- The Now - Pragmatic Improvement

PRAGMATIC IMPROVEMENT

- Investment And Intelligence
- Courage, Strength, Wisdom
- Discipline

SOME REQUIREMENTS THESES

- No One Can Write A Requirement
- Technology Is not Totally Predictable
- No Requirements Statement Is Ever Perfect
- Almost All Requirements Statements Have Some Value

TOOLS

- Analysis
- Allocation
- Trade-off/Balance
- Margin Analysis
- Simulation/Gaming
- Economic Bounds
- Revise - Recycle - Reevaluate - Redetermine

WHO CAN WRITE REQUIREMENTS?

- Users?
- Systems Engineers?
- Developers?
- Managers?
- Surrogates?
- Committees?
- War Gamers?
- No One?

A PROCESS, NOT AN EVENT

- Balanced Initial Position - Architects, Users, Managers
- Cyclical Demonstration And Verification - Developers, Users, Managers
- Accept-Reject-Change Cycles-Engineers, Users, Managers
- Go When You're Ready - Engineers, Users, Managers

ACTION WATCHWORDS

"T

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PHASES OF REQUIREMENTS PRACTICE

- The Kinder-Gentler Era
- The Cost-Plus Era
- The Truman Committee
- The Military Industrial Complex Era
- MIL-STD-490
- Vietnam
- DARs, FARs, And NDI
- The Procurement Integrity Era
- The Glasnost Era

REQUIREMENTS AND THE DEVELOPMENT PROCESS

- The Promise
- The Goal
- The Berlin Wall
- The Ratchet Alterable Berlin Wall
- The Continued Balancing Act

"Once in a dark, damp cellar in Burgundy, I sat at lunch time next to an older man whose great grandfather had worked the vine on the same plots this man worked. Someone cut some cheeses, bread and sandwich meats and passed them around. The owner opened a couple of bottles of exemplary, if not prestigious, red wine.

The man next to me poured himself two-thirds of a water tumbler full and sat on a wooden wine case. He bit into the thick sandwich he had made himself and raised his glass. He didn't study the color and the brilliance; he didn't sniff at it; his nostril didn't quiver. He took a healthy draft of the wine and put the glass down to take another bite of his sandwich.

"Bonne," he murmured. "Bonne."

Anthony Spinazzola

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